

REPORT NUMBER: RED-04-01

REPORT ON EARLY DISTRESS (RED)

**Investigation of Shoulder Heave Problems
on
I-90, Monroe County (and other State Hwys)**

FINAL REPORT



OCTOBER 2001

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				14. Sponsoring Agency Code WisDOT Research Study # RED-01-0-01	
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16. Abstract A Report of Early Distress (RED) for heaved shoulders adjacent to Portland Cement Concrete (PCC) mainline pavement was received from WisDOT District 5 staff in January of 2001. The asphalt shoulders had risen 2 inches (more than 2 inches in some areas) above the mainline concrete. In many areas, the shoulders match the mainline elevation, but rise significantly in the first 1 to 2 feet of shoulder. That 1 to 2 feet of shoulder is broken up with severe signs of distress (cracking). This condition has created maintenance problems associated with winter snow removal operations. It appears that for projects constructed with open graded base course, the probable root cause of the of the problem is differential frost heave due to dissimilar base materials under the shoulders. Unsealed longitudinal edge joints are likely exacerbating the problem. For projects constructed with dense graded base course, the probable root cause of the heaving is inconsistent/insufficient compactions efforts immediately adjacent to the mainline pavement. Again, unsealed longitudinal edge joints are likely exacerbating this condition. The primary recommendations made in this report are to route and seal the longitudinal edge joints for all new construction as well as existing pavements. For shoulders with severe distress in the form of cracking and breakup, consideration should be given to full or partial replacement of the shoulder.					
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On
I-90, Monroe County (and other Interstate Hwys)

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WisDOT Highway Research Study # RED 01-01

By

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For

WISCONSIN DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT
BUREAU OF HIGHWAY CONSTRUCTION
PAVEMENTS SECTION
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October 2001

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INTRODUCTION

A Report of Early Distress (RED) for I-90 in Monroe County was received from David Bohnsack, WisDOT District 5 Pavement Engineer in January of 2001. A concrete paving project constructed in 1994 with asphaltic shoulders was showing early distress in the form of heaved shoulders (and resulting cracking). This problem has been observed on various other projects around the state as well and has become a significant maintenance issue. As a result, an investigation was conducted to determine the probable causes and reasons for the early distress. This report describes the findings of that investigation along with recommendations and an implementation plan to address the problem(s).

PROJECT OVERVIEW

Highway	: IH-90 East & West, Monroe County
Project ID	: 1077-03-71
Project Location	: CTH M – USH 12 / STH 16
Date Constructed	: 1994
Edge Drains	: Post-pave installation

As stated in the original Report of Early Distress (See Appendix A), “The shoulders have risen approximately 2 or more inches above the mainline concrete in some areas. In many areas, the shoulders match the mainline but rise significantly in the first 1–2 feet of shoulder. That 1-2 foot area is broken up with signs of severe distress.”

The probable cause of distress as stated in the original RED report (a one page submittal form) is “Frost heave – there is Open Graded Base Course (OGBC) under the mainline pavement with dense graded crushed aggregate base course (DGCABC) under the shoulders.” The typical section (See Appendix C) shows the OGBC extending out under the first 1-2 feet of shoulder. “The dense graded material holds moisture and heaves when frozen.”

Consultation with WisDOT’s Chief Geotechnical Engineer, Bruce Pfister, concurred that the probable cause of the distress for this project is differential heaving due to the dissimilar base

course materials under the shoulder; however, two main concerns were raised about the proposed recommendation (from the original RED submittal form) of extending the same base course materials to the outside edge of the shoulder as that which was placed under the mainline pavement. The first concern was that the edge drain should then be moved closer to the outside edge of the shoulder and that this action could impact construction activities, namely, haul road considerations. The second concern was that this would add to the cost of district projects by substantially increasing the amount of open graded base course needed to place across the entire cross section (for those projects constructed with OGBC).

DISCUSSION / AUXILIARY INFORMATION

On August 16th, this report was presented to WisDOT's Pavement Structural Design User Group (PSDUG) for discussion and input. The group did not favor extending the same base course materials underneath the entire cross section, as this would add significant costs to their projects (for those projects constructed with open graded base course). They did agree however, that all new construction and existing PCC pavements with asphalt shoulders, should have the longitudinal joints routed and sealed to prevent water from entering the base course materials at the pavement/shoulder interface.

To clarify, the pavement that "initiated" the original RED submittal was constructed with open graded base course, however it was learned that this problem has been observed on projects constructed with dense graded base course as well.

In a memo discussing possible contributing causes to the shoulder heave problem, WisDOT District 6 Pavement Engineer Randy Luedtke offered further explanation: "My conclusion has always been that as stated in the report that it is a frost heave problem, but the problem area is caused through the construction process when the shoulder base is placed. Since the operators have been told to be careful next to the edge of the new slab, compaction efforts in the 1-2 foot area adjacent to the slab are less than stellar and not uniform. The trench itself (for drain tile) in the OGBC sections also can add to the compaction problems. Also, remember that sometimes

the fine-graded material from the string line grading can end up in this area.” Thus, it appears that inconsistent / insufficient compaction efforts immediately adjacent to the mainline pavement may be contributing to the heaved and distressed shoulders for projects constructed with both open graded base courses and those constructed with dense graded base courses as well.

SUMMARY

In summary, frost heave is the cause of the heaved shoulders and the resultant cracking associated with it for projects constructed with open graded base course due to dissimilar base course materials underneath the shoulders (differential heaving). The problem is likely exacerbated by unsealed longitudinal edge joints between the shoulder and mainline pavement. In addition, it appears that inconsistent/insufficient compaction efforts in the 1-2 foot area of the shoulder adjacent to the mainline pavement may be contributing to the problem for all projects as previously discussed.

The importance of sealing the longitudinal edge joint cannot be underestimated according to a Minnesota Department of Transportation research study titled “Sealing Longitudinal Edge Joints on Drained Concrete Pavements”. Their initial results indicated that “sealing the edge joint on concrete pavements reduces the volume of water drained through the edge drains by as much as 85%. These findings suggest that one of the primary sources of infiltration into the pavement system is through the edge joint. Therefore, it may be cost effective to seal joints to prevent infiltration, and thus reduce the potential for shoulder settlement, pavement deterioration and distress.” They came to the conclusion that “sealing the longitudinal edge joint should be considered as a preventative maintenance program.” It is interesting to note that the implications of this research for existing pavement drainage practices were “1) Edge drains primarily drain the edge joint. 2) The presence of edge drains does not necessarily provide positive drainage for the entire pavement system, and 3) Evaluating drainage for pavement systems requires more than measuring outflow from edge drains.”

It is noted here for informational purposes, that WisDOT is currently investigating if the use of edge drains and open graded base courses are indeed giving us added performance by extending pavement service life based on cost effectiveness. The “Effectiveness of Concrete Pavement Underdrain and its Placement” is a formal research study in progress under the auspices of the Wisconsin Highway Research Program (WHRP), while the Pavements Section in the Bureau of Highway Construction is currently evaluating the cost effectiveness of open graded base courses based on ten years of data. Either singly or together, these two efforts may effect possible future changes in WisDOT construction practices, which should further help alleviate some of the causes of heaved shoulders throughout the state.

In addition WHRP is also administering a formal research study titled “Performance of Shoulders Adjacent to Concrete Pavements”, which, according to the work plan is expected to address the following objectives: “1) develop guidelines for the selection, design and construction of shoulders adjacent to concrete pavements to achieve optimum performance; 2) determine the cost effectiveness of paved shoulders; and 3) broaden WisDOT knowledge-base on the design, construction, performance, cost and maintenance practices of shoulders adjacent to concrete pavements.”

Lastly, it was learned late in this investigation that WisDOT District 1 Area Maintenance Engineer Kirk Konkel did in fact, route and seal the longitudinal edge joints on various projects within his jurisdiction experiencing problems with heaved shoulders. The heaved shoulders were causing excessive wear on the county snowplow blades. Mr. Konkel adds that “...it seems to have solved the problem, the snowplow blades don’t show near the amount of wear as before.” This is a strong indication of the effectiveness of routing and sealing the longitudinal edge joint to prevent or minimize the degree of heaving.

CONCLUSIONS

1. For projects constructed with open graded base course, the probable root cause of the problem is frost heave due to dissimilar base materials under the shoulders (differential heaving). Unsealed longitudinal edge joints are likely exacerbating the problem.
2. For projects constructed with dense graded base course, the probable root cause of the heaving is inconsistent/insufficient compaction efforts immediately adjacent to the mainline pavement. Again, unsealed longitudinal edge joints are likely exacerbating this condition.
3. It is likely that shoulder base course placement and compaction operations immediately adjacent to the mainline pavement may be a contributing factor in the heaving for all projects as previously discussed.
4. The distress is most pronounced at the interface of the two dissimilar base course materials (for those projects constructed with open graded base course).
5. The problem exists throughout the state and has become a significant issue facing maintenance personnel.

RECOMMENDATIONS

1. Route and seal the longitudinal joint between the shoulders and mainline pavement to prevent excess water from entering the base course materials below the shoulders. This applies to all new construction as well as existing pavements. Existing shoulders with severe breakup and cracking would not benefit much from this and thus consideration should be given to full or partial replacement in this case.
2. A construction note explaining the recommended procedure of routing and sealing the longitudinal edge joint will be issued for the next 2 years.
3. Develop a standard detail drawing to include the routing and sealing of the longitudinal edge joints.
4. Issue a construction note to have more attention paid to compaction efforts immediately adjacent to the mainline pavement for the next 2 years.
5. Await the results of the three research undertakings mentioned in the summary portion of the report prior to any further action beyond the recommendations in this report.

APPENDIX A

(Original RED Report)

REPORT ON EARLY DISTRESS (RED) IN HIGHWAYS AND BRIDGES

1. Location of Apparent Distress:

Highway: IH 90 E W S N

Date Constructed: 1994

Project ID: 1077-03-71

City / Village:

Bridge ID:

County: Monroe

Project Begin / End: CTH M – USH 12/STH 16

Other Location Info: (Distance, Direction, Reference Point, Intersection, Landmark, etc.)

CTH M to Tomah Section, both shoulders on both roadways.

2. Highway / Bridge Element where Distress Appears: (x)

Highway: Pavement X Shoulder Embankment Drainage Marking/Signing
 Hardware

Bridge: Deck Railing Expansion Joint Substructure Other

Explanation:

The asphalt shoulders have risen $\pm 2''$ above the mainline concrete in some areas. In many areas, the shoulders match the mainline but rise significantly in the first 1 to 2' of shoulder. That 1 to 2' area is broken up with signs of severe distress.

3. Probable Cause of Distress:

Frost heave – There is OGBC under the mainline pavement with dense grade CABC under the shoulders. The dense graded material holds moisture and heaves when frozen. The typical section shows OGBC under the first 1 to 2' of shoulder. I haven't found out yet, but it is possible that recycled concrete was used as base for the shoulders.

4. Recommended Action / Correction (How would you handle it?):

Immediate action is maintenance on the shoulders – Neither the transverse cracking nor the longitudinal joint between the asphalt and concrete is being sealed.

For future projects – Either eliminate the OGBC or place across entire x-section. There must be similar materials used as base to eliminate the damage caused by this heaving.

5. Report Submitted by: David Bohnsack

Telephone #: (608) 785-9781

Bureau, Section, Unit: District 5 Technical Services Section

2nd Name, Unit &

Phone: _____

District: 1 2 3 4 5 6 7 8 CO (Circle One)

Date Submitted: January 16, 2001

APPENDIX B

(Photos)



Print 1. Showing shoulder heave and break up on the east bound lanes.



Print 2. View of shoulder breaking up on the west bound lanes.



Print 3. Close-up of the shoulder heave and subsequent break up.



Print 4. Straight edge used to show relative shoulder heaving height (approx. 2 inches).



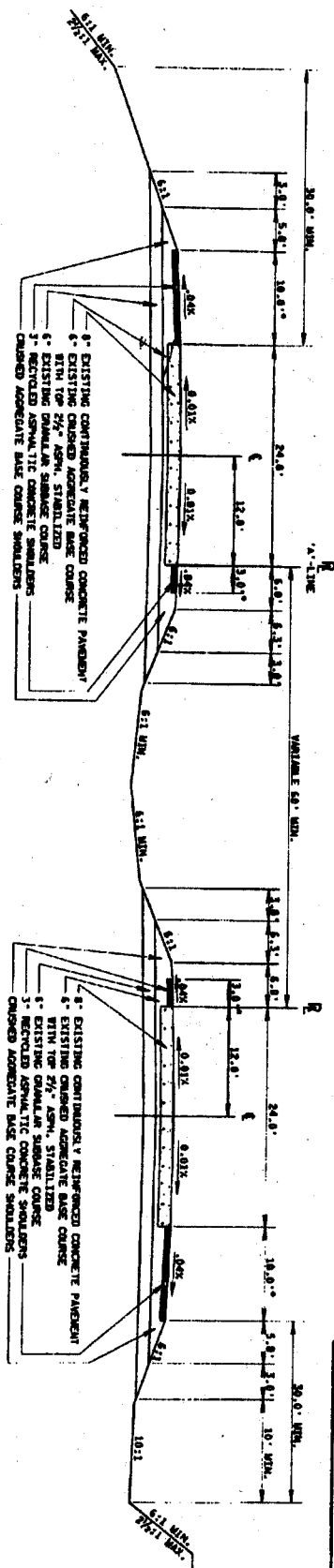
Print 5. Another view of a distressed area of a heaved shoulder.



Print 6. Showing the approximate 2 inches of shoulder heaving with a straight edge.

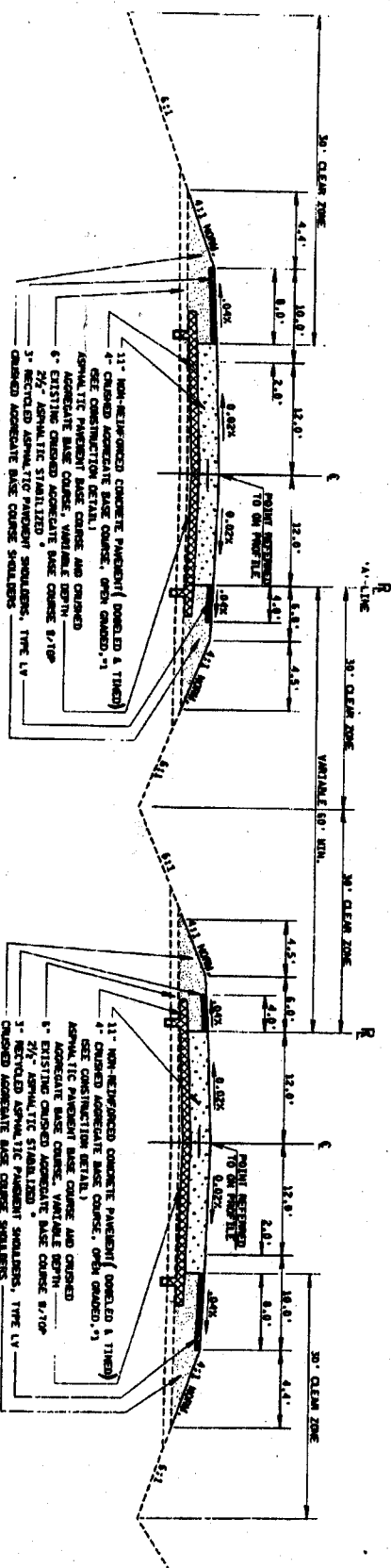
APPENDIX C

(Construction Plans & Standard Detail Drawings)



TYPICAL EXISTING TANGENT SECTION

*THE PAVED SHOULDER WIDTH FROM STA 2103+00 TO STA 2128+00 IS 7.0' ON THE OUTSIDE SHOULDERS AND 4.0' ON THE MEDIAN SHOULDERS.



TYPICAL FINISHED TANGENT SECTION

WESTBROOK	A-1-LINE	ESTRIBO	MAIN LINE
STA 2213.4+05	- STA 2142.4+60	STA 2213+90	- STA 2123+50
STA 2240.4+02	- STA 2142.4+60	STA 2253+10	- STA 2126+30
STA 2155.4+55	- STA 2185.4+70	STA 2179+05	- STA 2180+50
STA 2179.4+56	- STA 2185.4+70	STA 2216+10	- STA 2129+17
STA 2210.4+05	- STA 2127.4+08		

- EXISTING CHANGED APPROPRIATE BASE COURSE TO BE MAINTAINED AT A RERINDED DEPTH OF 4". WHEN PROFILE AS NOTED ON PLANS REDUCES THIS LIMIT, THE DIFFERENCE SHALL BE MADE UP BY INCREASING OF EXISTING SURFACE AND RELACING WITH A RERINDED DEPTH OF 4" CORRESPONDING APPROPRIATE BASE COURSE.

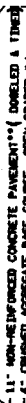
SEE TYPICAL UNDOGROUT SECTION - MAINLINE.

STATE PROJECT NUMBER	1077-03-7	SHEET 43	2.1
TYPICAL SECTIONS			
IN 90 MONROE COUNTY			



RESTROOM 'A' LINE		EASTBOUND MAIN LINE	
STA 2103'-00"	STA 2104'-00"	STA 2103'-00"	STA 2104'-00"
STA 2129'-00"	STA 2135'-00"	STA 2129'-00"	STA 2130'-00"
STA 2138'-00"	STA 2140'-00"	STA 2139'-00"	STA 2140'-00"
STA 2148'-00"	STA 2149'-00"	STA 2149'-00"	STA 2150'-00"
STA 2158'-00"	STA 2159'-00"	STA 2158'-00"	STA 2159'-00"
STA 2213'-00"	STA 2214'-00"	STA 2213'-00"	STA 2214'-00"
STA 2233'-00"	STA 2234'-00"	STA 2233'-00"	STA 2234'-00"
STA 2283'-00"	STA 2284'-00"	STA 2283'-00"	STA 2284'-00"

NOTE: EXISTING CRUSHED AGGREGATE BASE COURSE TO BE MAINTAINED AT A MINIMUM DEPTH OF 4". WHEN PROFILE AS NOTED ON PLANS REDUCES THIS LIMIT, THE DIFFERENCE SHALL BE MADE UP BY UNDERCUT OF EXISTING SUBBASE AND REPLACING WITH A MINIMUM DEPTH OF 4" CRUSHED AGGREGATE BASE COURSE.

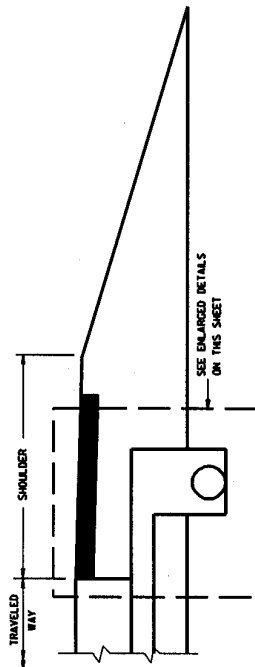


WESTBOUND 'A'-LINE
STA 2103'A+00 - STA 2117'A+05

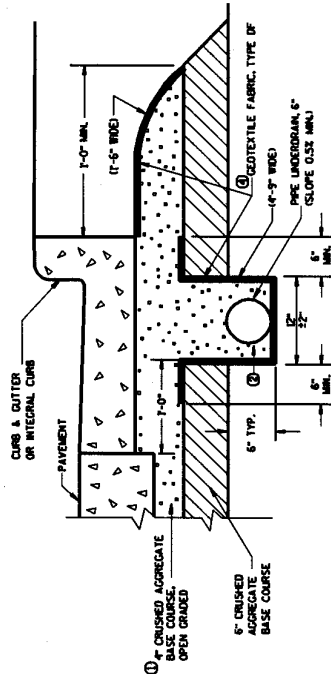
.. FROM STA 2103+00 TO STA 2104+00 AND STA 2103+00 TO STA 2104+00 THE CONCRETE PAVEMENT SHALL TAPER FROM 8" TO 1" AND SHALL BE CONTINUOUSLY REINFORCED. (SEE PAVEMENT TERMINAL UNIT DETAIL DRAWINGS).

NOTES

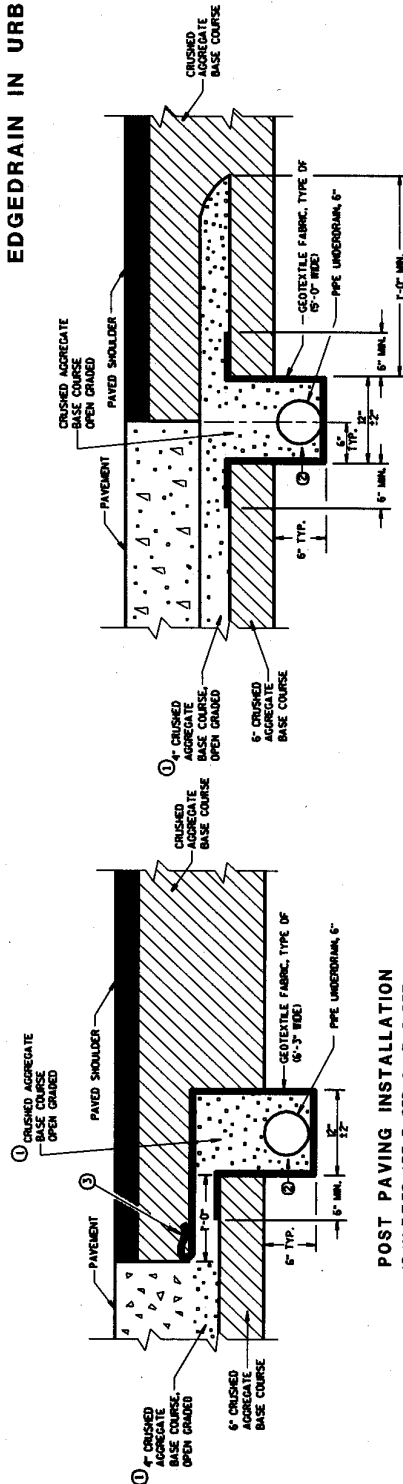
- THE DIMENSIONS SHOWN ON THE TYPICAL CROSS SECTIONS WILL GOVERN IN THE EVENT THERE IS A CONFLICT WITH THE DETAILS SHOWN ON THIS DRAWING.
- PPE UNDERDRAIN SHALL BE Laid PARALLEL TO THE GRADE OF THE ROADWAY.
- ① THE GRADATION OF THE OPEN GRADED BASE COURSE SHALL BE EITHER NO. 1 OR NO. 2 AS SPECIFIED ELSEWHERE IN THE CONTRACT.
- ② FRENCH SAGRELL WILL BE PAID FOR AS CRUSHED AGGREGATE BASE COURSE, OPEN GRADED NO. 1 OR NO. 2 AS SPECIFIED.
- ③ FOLD OVER EXCESS GEOTEXTILE FABRIC AT THIS LOCATION.
- ④ TOTAL FABRIC WIDTH IS 6'-3" FOR PAYMENT.



RURAL CROSS SECTION



EDGEDRAIN IN URBAN ROADWAY



POST PAVING INSTALLATION
(QUANTITIES ARE BASED ON THIS DETAIL)

PRE-PAVING INSTALLATION ALTERNATE

EDGEDRAIN IN RURAL ROADWAY

EDGEDRAIN AND CRUSHED AGGREGATE BASE COURSE, OPEN GRADED, NO. 1 OR NO. 2
STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
APPROVED
DATE
CHIEF ROADWAY DEVELOPMENT ENGINEER

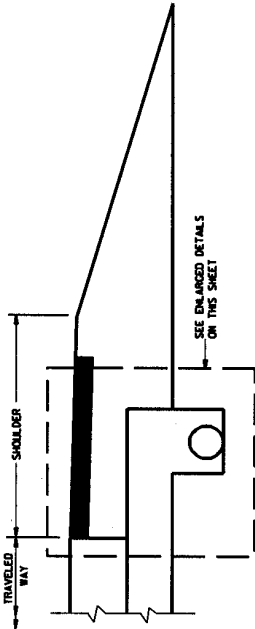
S.D.D. 8 D 15-3b

NOTES

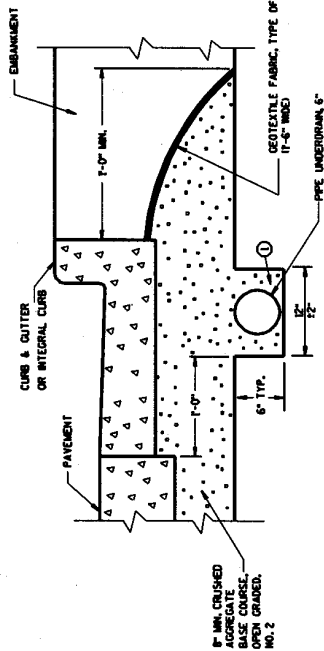
THE DIMENSIONS SHOWN ON THE TYPICAL CROSS SECTIONS WILL GOVERN IN THE EVENT THERE IS A CONFLICT WITH THE DETAILS SHOWN ON THIS DRAWING.

PIPE UNDERDRAIN SHALL BE Laid PARALLEL TO THE GRADE OF THE ROADWAY.

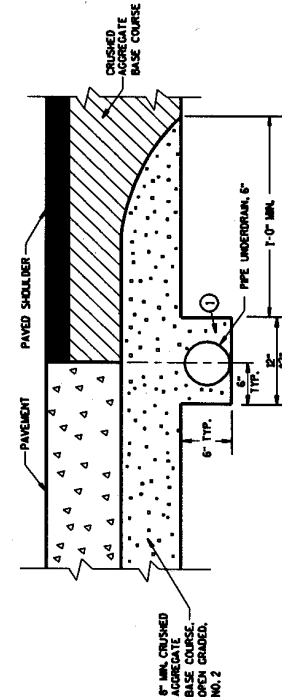
- ① TRENCH BACKFILL WILL BE PAID FOR AS CRUSHED AGGREGATE BASE COURSE, OPEN GRADED NO. 2.



RURAL CROSS SECTION

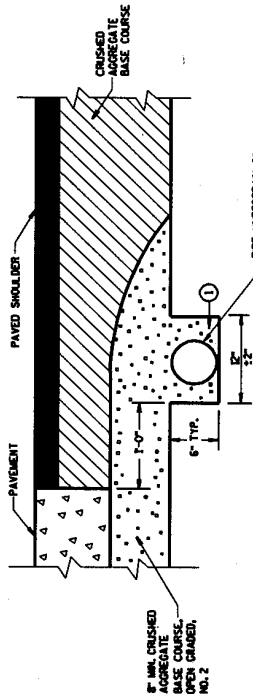


EDGEDRAIN IN URBAN ROADWAY



PRE-PAVING INSTALLATION ALTERNATIVE

EDGEDRAIN IN RURAL ROADWAY



POST PAVING INSTALLATION
(QUANTITIES ARE BASED ON THIS DETAIL)

EDGEDRAIN AND CRUSHED AGGREGATE BASE COURSE, OPEN GRADED, NO. 2 DETAILS
STATE OF WISCONSIN DEPARTMENT OF TRANSPORTATION
APPROVED
DATE _____ PIMA
CHIEF ROADWAY DEVELOPMENT ENGINEER

S.D.D. 8 D 15-3c

S.D.D. 8 D 15-3c

APPENDIX D

(Implementation Plan)

Research Study Recommendation And Implementation Plan

Highway Research Study ID: RED-01-01

WisDOT Report #: RED-04-01

Title: “Report on Early Distress (RED), Investigation of Shoulder Heave Problems on I-90, Monroe County (and other State Hwys)”

WisDOT Study Manager: Joe Wilson, Technology Advancement Specialist

Background Problem Statement: A Report of Early Distress (RED) for heaved asphalt shoulders adjacent to Portland Cement Concrete (PCC) mainline pavement was received from District 5 staff in January of 2001. This condition has been observed throughout the state and presents problems for maintenance personnel during winter snow removal operations.

Study Conclusions:

1. For projects constructed with open graded base courses, the probable root cause of the problem is frost heave due to dissimilar base materials under the shoulders (differential heaving). Unsealed longitudinal edge joints are likely exacerbating the problem.
2. For projects constructed with dense graded base courses, the probable root cause of the heaving is inconsistent/insufficient compaction efforts immediately adjacent to the mainline pavement. Again, unsealed longitudinal edge joints are likely exacerbating this condition.
3. It is likely that shoulder base course placement and compaction operations immediately adjacent to the mainline pavement may be a contributing factor in the heaving for all projects as previously discussed in the RED report.
4. The distress is most pronounced at the interface of the two dissimilar base course materials (for those projects constructed with open graded base course).
5. The problem exists throughout the state and has become a significant issue facing maintenance personnel.

Study Recommendations:

1. Route and seal the longitudinal joint between the shoulders and mainline pavement to prevent excess water from entering the base course materials below the shoulders. This applies to all new construction as well as existing pavements. Existing shoulders with severe breakup and cracking would not benefit much from this and thus consideration should be given to full or partial replacement in this case.
2. A construction note explaining the recommended procedure of routing and sealing the longitudinal edge joint will be issued for the next 2 years.
3. Develop the standard detail drawing to include the routing and sealing of the longitudinal edge joints.
4. Issue a construction note to have more attention paid to compaction efforts immediately adjacent to the mainline pavement for the next 2 years.
5. Await the results of the three research undertakings mentioned in the summary portion of the report prior to any further action beyond the recommendations in this report.

Implementation Plans:

1. Develop the standard detail drawing to include the routing and sealing of the longitudinal edge joints.
2. Issue a construction note explaining the recommended procedure of routing and sealing the longitudinal edge joints for the next 2 years.
3. Issue a construction note to have more attention paid to compaction efforts immediately adjacent to the mainline pavement for the next 2 years.